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Energy Optimization Audit at Humphreys Engineer Center

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and Marvin Keefover

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Final Report

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Abstract: This work conducted an Energy Optimization Assessment at the Humphreys Engineer Center, Alexandria, VA, to identify energy inefficiencies and wastes, and to propose energy-related projects that could enable the installation to better meet the energy reduction requirements mandated by Executive Order 13123, the Energy Policy Act (EPACT) of 2005, and the Energy Independence and Security Act (EISA) of 2007. The study was conducted by a professional Energy Team, composed of researchers from the Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) and other subject matter experts. The Assessment included a Level I study of the installation administrative buildings, and an analysis of their building envelopes, ventilation air systems, and lighting. The study identified 31 different energy conservation measures (ECMs), including measures related to the building envelope, lighting, HVAC and electrical systems that, if implemented, would reduce Humphreys Engineer Center annual energy use by up to 14,500 MMBtu/yr and 2,300 MWh/yr (depending on the combination of ECMs implemented). Eighteen of the proposed energy conservation measures were quantified economically and have a potential of annual saving of more than $200,000.

Executive Summary

This work conducted an Energy Optimization Assessment at the Humphreys Engineer Center, Alexandria, VA, to identify energy inefficiencies and wastes, and to propose energy-related projects that could enable the installation to better meet the energy reduction requirements mandated by Executive Order 13123, the Energy Policy Act (EPACT) of 2005, and the Energy Independence and Security Act (EISA) of 2007. The study was conducted by a professional Energy Team, composed of researchers from the Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) and other subject matter experts.

The Assessment included a Level I study and an analysis of their building envelopes, ventilation air systems, and lighting of the installation's professional office buildings:

- Kingman (B2593)
- Casey (B2594)
- Cude (B2592)
- Fitness Center/Mailroom (B2584)
- Museum/Motor Pool (B2585)
- Warehouse (B2582)
- Grounds Equipment (B2583)
- Bunkers (B2590, 91 and B2595).

The study identified 31 different energy conservation measures (economically quantified ECMs are listed in Table ES1), including measures related to the building envelope, lighting, HVAC and electrical systems. If implemented, these would reduce Humphreys Engineer Center annual energy use by up to 14,500 MMBtu/yr and 2,300 MWh/ yr (depending on the combination of ECMs implemented). Eighteen of the proposed energy conservation measures were quantified economically in this study. They have a potential annual savings of more than $200,000 of a capital investment of about $5 million (see Table ES1).

The Building Envelope category consists of 19 Building Envelope ECMs. Improvement of wall insulation and increasing of air tightness are very important measures that have potential for improvement of thermal comfort, reducing moisture condensation in the cooling season, and would result in thermal savings with a payback of under 12 yrs. Additionally, the ECMs can result in reduced HVAC requirements for heating and cooling.

Four HVAC system-related ECMs range from upgrade and improvement of existing systems in Kingman and Cude buildings to adding controls allowing for temperature setback in smaller buildings. These ECMs have attractive paybacks ranging from under 2 yrs to under 9 yrs.

Seven identified Lighting ECMs, ranging from changing lamp fixtures and installing occupancy sensors to changing main switchboards and obsolete motor control centers. These ECMs have paybacks ranging from less than a year to under 9 yrs.

The Electrical ECM is focused on replacing inefficient motors with a Federal Energy Management Program (FEMP) designated motors in a group of buildings with an average payback of 3.1. yrs.

This work recommends that Humphreys Engineer Center implement the identified low-cost, short-term payback ECMs (lighting, electrical) as a part of the annual O&M program. This work also identified major energy savings that will result from building insulation and that will require significant investments. This work also recommends that the installation consider implementation of these projects using an Energy Performance Contracting mechanism, or through Federal technology demonstration programs. These projects can be packaged with the HVAC system improvement projects, which in combination will result in a reduction of first costs, thereby becoming more attractive to ESPC contractors.

Table ES1. Summary of ECMs

ECM #	ECM Description	Electrical Savings		Thermal		Maintenance $/yr	Total Savings $/yr	Investment $	Simple Payback yrs
		KWh/yr	$/yr	MMBtu/yr	$/yr				
BE-1A	Insulate the Kingman Building (Bldg 2593) on the exterior with a layer of 3-in. rigid insulation and a drainable External Insulation Façade System (EIFS).			1,805	21,670		21,670	260,000	12
BE-1B	Add curtain wall with insulated Low-E gazing and with insulated metal backpan spandrel areas of the Kingman Building (Bldg 2593) .			1,094	13,126		13,126	774,000	59
BE-1D	Take the ceiling down n the Kingman Building (Bldg 2593) hearing room, and insulate and seal the roof from inside with 3-in. of spray polyurethane foam.			2,500	25,000		25,000	550,000	22
BE-2A	Insulate the Casey Building (Bldg 2594) on the exterior with a layer of 3-in. rigid insulation and drainable EIFS .			1736	20,830		20,830	250,000	12
BE-3A	Install 3-in. of drainable EIFS on the face of the precast concrete of the Cude Building (Bldg 2592).			2,848	34,170		34,170	410,000	12
BE-3B	Removed the single glazing adaptor, and replace existing single pain window glass with insulating Low E. in the Cude Building (Bldg 2592).			1,983	23,797		23,797	1,092,000	46
BE-3E	Add a vestibule to the courtyard door in the Cude Building (Bldg 2592). Doors should be regasketed.			420	5,000		5,000	20,000	4
BE-5B	Insulate bunker building (Bldg 2591) with drainable EIFS. Replace existing failed EIFS with new drainable EIFS .			567	6,800		6,800	82,000	12
BE-5D	Gasket doors in bunker buildings 2590, 2591, 2595.								< 1
LI-1	Remove center lamp from the 3-lamp fixtures in private offices and work spaces around the perimeter in the Kingman Building (Bldg 2593).	163,800	8,026				8,026	35,250	4.5
LI-2	Complete the installation of occupancy sensors in restrooms in the Cude Building (Bldg 2592).	2,453 per restroom	120 /restroom						< 1
LI-3	Replace the obsolete main switchboard in the Cude Building (Bldg 2592).		5,000 /occurrence				10,000	50,000	5
LI-4	Replace the obsolete motor control centers in the Cude Building (Bldg 2592).		2,500 /occurrence				5,000	15,000	3
LI-5	LI-5 Install skylights and turn off the lights during the day at the Fitness Center/Mailroom (B2584), Museum/Motor Pool (B2585), Warehouse (B2582).	10,920	535				535	5000	9

ECM #	ECM Description	Electrical Savings		Thermal		Maintenance $/yr	Total Savings $/yr	Investment $	Simple Payback yrs
		KWh/yr	$/yr	MMBtu/yr	$/yr				
LI-6	Upgrade the lighting fixtures in the Grounds Equipment Building (B2583), to new lower wattage, more energy efficient types.	2,808	138				138	1175	8.5
LI-7	Upgrade the lamps and ballasts in the existing lighting fixtures in the bunker facilities, Bldgs 2590 and 2591, to new lower wattage, more energy efficient types.							18,800 94/per fixture	20
HVAC-1	Upgrade HVAC System in Kingman Building, (Bldg 2593):								
	1a	545,000	26,700	1,270	15,200	-18,750	60,650	628,000	10.4
	1b	446,000	21,800	1,270	15,200	18,750	55,750	484,000	8.7
HVAC-2	Replace HVAC System with variable air volume (VAV) in Cude Building (Bldg 2592).	961,000	47,100	1,175	14,100		61,200	634,000	10.4
HVAC-3	Improve HVAC System Controls in Cude Building (Bldg 2592).	596,000	29,200	2,255	27,000		56,200	104,000	1.8
HVAC-4	HVAC-5. Temperature Setback in Fitness Center/Mailroom (B2584), Museum/Motor Pool (B2585), Warehouse (B2582).			242	2,900		2,900	8,000	2.8
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Preface

This work was funded by the Humphreys Engineer Center Support Activity (HECSA), which maintains oversight of the Humphreys Engineer Center (HEC) and has authority to maintain all of the HEC buildings. The technical monitor was Duane Murphy, Energy Manager, Humphreys Engineer Center.

The work was managed and executed by the Army Corps of Engineers Engineering and Research Center, Energy Branch (CF-E) of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL). The CERL principal investigator was Dr. Alexander Zhivov. Appreciation is owed to Duane Murphy, James Tidwell, Jim Groves and Skip Fitzgerald (HECSA), Mark Melendy and Ky Lamm (CFS-BHS JV), Marc LaFrance and Cyrus Nasseri, U.S. Department of Energy (DOE) and Bill Preston, Darrell Smith and Joshua Early (DOE Contractors). The associated Technical Director was Martin J. Savoie, CEERD-CV-T. The Director of ERDC-CERL is Dr. Ilker R. Adiguzel.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL Gary E. Johnston, and the Director of ERDC is Dr. James R. Houston.

Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
British thermal units (BTU, International Table)	1,055.056	joules
MMBtu	0.293	MWh
MBtu	1,000	Btu
MMBtu	1,000,000	Btu
cubic feet	0.02831685	Cubic meters
cubic inches	1.6387064 E-05	Cubic meters
cubic yards	0.7645549	Cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.3048	meters
gallons (U.S. liquid)	3.785412 E-03	Cubic meters
inches	0.0254	meters
miles (U.S. statute)	1,609.347	meters
miles per hour	0.44704	meters per second
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters
square miles	2.589998 E+06	square meters
square yards	0.8361274	square meters
tons (2,000 pounds, mass)	907.1847	kilograms
tons (2,000 pounds, mass) per square foot	9,764.856	kilograms per square meter
yards	0.9144	meters

1 Introduction

Background

The Humphreys Engineer Center (HEC) is a U.S. Army Corps of Engineers (USACE) installation that occupies 579.45 acres, located approximately 19 miles south of USACE Headquarters in Washington, DC, at 7701 Telegraph Road in Alexandria, VA (Figure 1). The property is immediately adjacent to (but is not part of) the Fort Belvoir Military Reservation.

HEC is now primarily an administrative and research facility. Four large buildings house most of these activities. The Kingman Building (Bldg 2593), constructed in 1973, is an attractive four-story precast stone building surrounded by terraces and landscaping. The Casey Building (Bldg 2594), constructed in 1982, contains two stories and is also a high quality precast stone building. The Hall Building (Bldg 2596) is a new building that is approximately 128,000 gross sq ft in size.

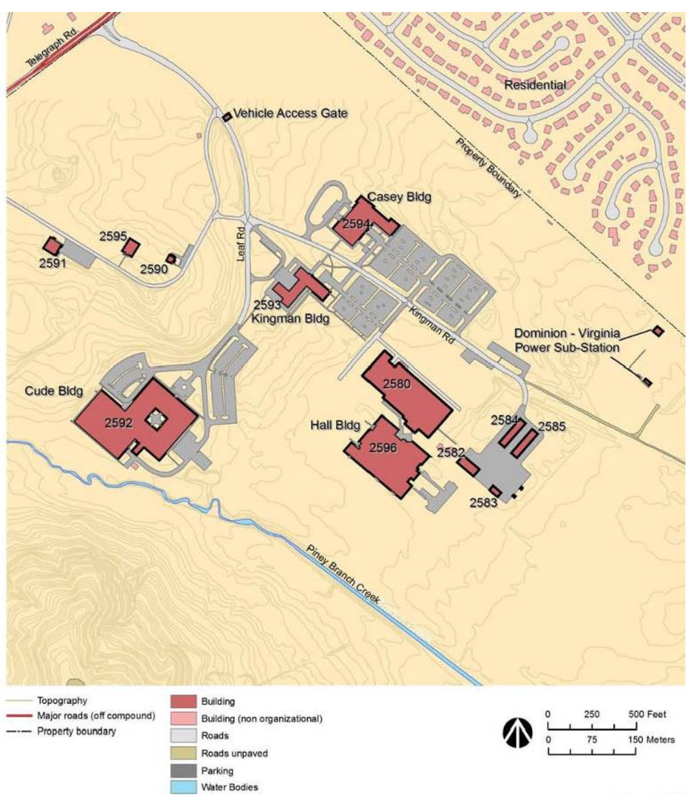

Figure 1. Humphreys Engineering Center existing buildings (from the Master Plan).

These three buildings accommodate administration and training activities. Research and development activities are located in the one-story, brick-faced Cude Building (Bldg 2592), which was constructed in 1974. A matching addition to the Cude Building was erected in 1988 as an annex.

The remaining facilities at HEC consist of several smaller maintenance and warehouse buildings and three concrete bunkers. HEC is a USACE civil works installation primarily concerned with administrative activities supporting its tenant organizations and the USACE. Approximately 1,027 personnel are employed at HEC. Table 1 lists the total floor areas for buildings at HEC.

Objectives

The objectives of this study were to identify energy inefficiencies and wastes at Humphreys Engineering Center and propose energy-related projects with applicable funding and execution methods that could enable the installations to better meet the energy reduction requirements mandated by Executive Order 13123, EPACT 2005, and EISA 2007.

Approach

ERDC/CERL implemented an Energy Assessment Protocol that was developed under the auspices of the IEA ECBCS Programme Annex 46 "Holistic Assessment Toolkit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo)." The protocol is designed to assist installation energy managers and Regional Energy Managers to develop energy conservation projects (self-help for energy managers). An energy assessment was conducted by the ERDC/CERL team in collaboration with private contractors with various technical expertise including such areas as building envelope, HVAC, lighting, and electrical systems.

Table 1. HEC Buildings floor areas.

Building number	2592	2593	2594	2582	2584	2585	2591
Building name	Cude	Kingman	CASEY	Warehouse	Fitness	Motor Pool	Bunker
Total Floor Area sq ft	171000	94320	82000	6000	7200	7200	7859

This protocol is based on the analysis of information available from the literature, training materials, the documented and undocumented practical experiences of contributors, and previous successful showcase energy assessments conducted by a diverse team of experts at the U.S. Army facilities.

Scope

The scope of this audit included a Level I study of three major office buildings: Kingman, Casey, and Cude Buildings, several smaller maintenance and warehouse buildings, and three concrete bunkers with an analysis of their building envelopes, ventilation, lighting, and electrical systems.

Mode of technology transfer

The results of this work will be presented to Humphreys Engineer Center management for their consideration for implementation and funding and as the basis for other currently conducted studies related to energy use planning. It is anticipated that this information will be disseminated through workshops, presentations, and professional industrial energy technology conferences. This report will also be made accessible through the World Wide Web (WWW) at: http://www.cecer.Army.mil

2 Installation Energy Use Rates and Historic Use

As reported by HEC, Table 1 lists electrical energy use, cost, and rate for 2006 and 2007; Table 2 lists natural gas use in Therms by different buildings in 2007-2008, and Table 4 lists total energy costs for FY07-08.

Table 2. Electrical energy use, cost and blended rate for 2006 and 2007

Month	kWh	Total $	Cost/kWh
2007			
Dec	1421000		
Nov	1666000		
Oct	1421000		
Sep	1750000	$86122	$0.049
Aug	1596000	$78006	$0.049
July	1582000	$76649	$0.048
June	1736000	$79824	$0.046
May	1393000	$63887	$0.046
April	1372000	$64257	$0.047
March	1379000	$62452	$0.045
Feb	1547000	$69736	$0.045
Jan	1582000	$72504	$0.046
2006			
Dec	1211000	88780	$0.073
Nov	1561000	81041	$0.052
Oct	1190000	88840	$0.075
Sep	1687000	$86,008	$0.051
Aug	1701000	$85,731	$0.050
July	1673000	$83,635	$0.050
June	1862000	$93,419	$0.050
May	1575000	$78,051	$0.050
April	1617000	$80,345	$0.050
March	1638000	$93,296	$0.057
Feb	1386000	$80,633	$0.058
Jan	1547000	$88,764	$0.057

Table 3. Natural gas use in Therms by different buildings in 2007-2008

2008								
Meter No.	R33940	P62681	J77233	H75575	605026	J66262	634903	P43300
Bldg No.	2580	2593	2594	unknown	2582	2591	2584	2592
Month								
May	5174	247	182	1	261	1	4	3746
April	5179	1871	916	193	593	66	84	6705
March	6268	4432	1359	515	801	189	88	8409
Feb	11672	10811	5133	742	930	567	2012	7867
Jan	8281	4206	1863	440	1015	674	2033	8576
2007								
Dec	7985	5668	3091	487	855	487	1597	7836
Nov	5656	2424	1486	255	581	145	926	568
Oct	3201	0	0	0	0	0	3	0
Sep	3355	0	0	0	0	0	4	0
Aug	2934	0	0	0	0	0	4	0
July	2953	0	0	0	0	0	35	0
June	2825	0	0	0	0	1	70	0

Table 4. HECSA energy costs for FY07-FY08.

Energy Type	Units	Unit Price
Electricity (blended rate)	KWh	$0.049/kWh
Natural Gas	Therms	$1.2

3 Energy Conservation Measures

Building envelope

BE-1. Kingman Building

Existing conditions

Exterior walls

The concrete structural frame is clad in precast concrete and the thermal bridging is extensive (Figure 2). The building is, for all intents and purposes, uninsulated (Figure 3).

Curtain wall

The anodized aluminum curtain wall (Figure 4) is mostly single-glazed storefront at first floor level and “zipper gasket” windows above.

Overhangs

Extensive overhangs (Figure 5) are a major source of air leakage because they are connected to the interior plenums.

Figure 2. Kingman Building.

Figure 3. Kingman Building (lack of) insulation.

Figure 4. Kingman Building curtain wall.

Figure 5. Kingman Building overhang.

Figure 6. Kingman Building entryway doors.

Roofing

The roofing is modified bitumen in good condition. The roofing over the dome in the multi-purpose room is EPDM (ethylene propylene diene M-class [rubber]).

Doors

There are three pairs of doors to the interior terrace (Figure 6) and exit with a high traffic. When open, they contribute to heating and cooling load increase on the HVAC systems.

Hearing Room

The ceiling has extensive air leaks. Since the room space is under negative pressure, air leaks result in hot humid air in summer and cold air in winter entraining the room from the outside. This contribute to increased heating and cooling load on the HVAC system and potential for mold problems.

Solutions

BE-1a

Insulate the building on the exterior with a layer of 3-in. rigid insulation and drainable EIFS.

BE-1b

Add curtain wall with insulated low-E glazing (Figure 7), and with insulated metal backpan spandrel areas. The existing glazing will be removed and the zipper gasket area blocked as shown.

BE-1c

Eliminate lighting in overhangs or replace the lighting fixtures with fixtures having an energy efficient design that does not leak air. Build an airtight bulkhead over the storefront above the ceiling, seal it, and insulate with spray polyurethane foam (SPF).

BE-1d

Take the ceiling in the hearing room down; insulate and seal the roof from the inside with 3-in. of spray polyurethane foam (SPF).

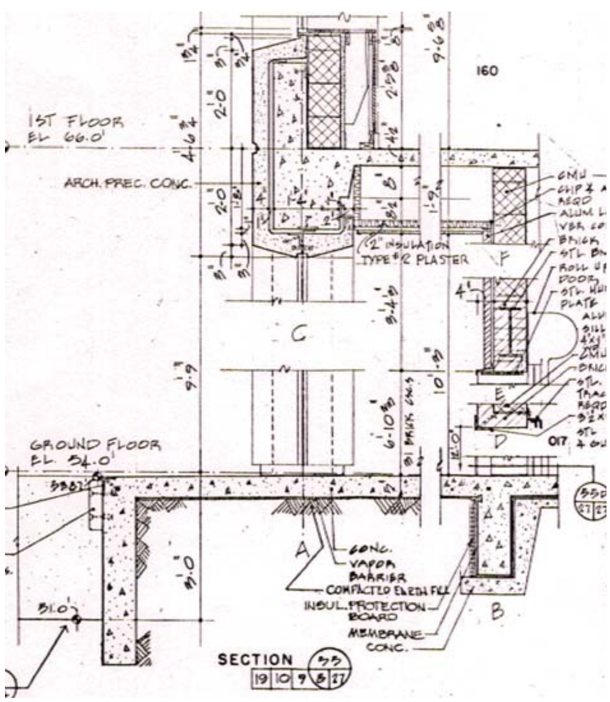

Figure 7. Kingman Building first-floor plan.

BE-1e

All doors need weather-stripping and thresholds.

BE-1f

Install a vestibule (Figure 8) at a high traffic doors and/or air curtains.

BE-2 Casey Building

Existing conditions.

Exterior walls

The Casey building (Figure 9), like the Kingman building, has a concrete structure with precast concrete cladding. Thermal bridging is extensive. The building is uninsulated.

Figure 8. Examples of vestibules for high traffic doors of administrative buildings.

Figure 9. Casey Building.

Windows

The windows are thermally broken aluminum with insulating glass (Figure 10).

Roof

The building has a protected membrane roof with modified bitumen in good condition.

Solutions

BE-2a

Insulate the building on the exterior with a layer of 3-in. rigid insulation and drainable EIFS.

BE-2b

Reduce air leakage through windows by proving new gasketing for operable units.

BE-3. Topographical Building (TEC)

Existing conditions

Exterior walls

The TEC building (Figure 11) has a steel structure with precast concrete cladding.

Figure 10. Casey Building windows.

Figure 11. Topographical Building (TEC).

Glazed curtain wall

Substantial East West facades and considerable glare and heat gain problems due to single glazing.

The adapter can be removed, and the glass replaced with insulating Low E. The 12-ft ceiling wastes energy; drop the ceiling to the level of the horizontal mullion. The top glass can be spandrel in front of an insulated backpan installed from the outside. Install exterior shading in the form of combination vertical and horizontal fins on the East and West facades. Add a vestibule to the courtyard door. Regasket the doors.

Solutions

BE-3a

Install 3-in. of drainable EIFS on the face of the precast concrete.

BE-3b

Remove the single glazing adaptor, and replace existing single pain window glass with insulating Low E.

BE-3c

Drop the 12-ft ceiling height to the level of the horizontal mullion to reduce energy consumption by reducing the volume of the air-conditioned space.

BE-3d

Spandrel the top glass in front of an insulated backpan installed from the outside. Install exterior shading in the form of combination vertical and horizontal fins on the East and West facades.

BE-3e

Add a vestibule to the courtyard door. Doors should be regasketed.

BE-4. Warehouse Buildings

Existing conditions

General

The warehouse buildings (Figures 12 and 13) are metal clad. The cladding (Figure 14) is rusting and in poor condition. The buildings are underused. The roofing is original.

Figure 12. Warehouse Buildings — side view.

Figure 13. Warehouse Buildings — entry.

Figure 14. Warehouse Buildings — metal cladding.

<u>Windows</u>

The windows (Figure 15) are steel, single glazed, and rusting—and have no weatherstripping.

Solutions

<u>BE-4a</u>

Option one. Build a new replacement building to consolidate the following functions:

- Fitness Center
- Museum cataloging lab.
- Warehouse
- Carwash and grounds equipment

Figure 15. Warehouse Buildings — windows.

BE-4b

Option two. Retrofit these buildings, including:

- Seal and insulated buildings with spray polyurethane foam (SPF), furring and drywall or by installing EIFS.
- Replace windows.
- Add vestibules to spaces larger than 3000 sq ft.
- Change roofs with reflective and better insulated.
- Replace overhead doors.
- Replace cladding.

BE-5. Bunker Buildings

Existing conditions

The Bunker buildings (Figure 16) are two-story structures that are underused. They are heated and cooled even though several of them house no function.

Solutions

BE-5a

Consider consolidating the space.

Figure 16. Bunker Building.


Figure 17. Failed EIFS on Bunker Building.

BE-5b

Insulate with drainable EIFS. Replace existing failed EIFS (Figure 17) with new drainable EIFS.

BE-5c

Replace roofs with new insulated roofs.

BE-5d

Gasket the doors.

BE cost calculations

The cost of EIFS is $12.95/sq ft (Dryvit Company + 20 percent)

The cost for retrofitting the opaque areas of:

Kingman Building:	$260,000
Casey Building:	$250,000
Topographical Building:	$410,000
Bunker Building:	$82,000

Cost of replacement glazing:

Kingman at $45/sq ft:	$774,000
Topographical Building at $35/sq ft:	1,092,000

Cost per vestibule: $20,000

Cost for retrofitting the Kingman building hearing room: $550,000

Simplified energy payback calculations

According to the Department of Energy's Office of Energy Efficiency and Renewable Energy the payback for adding insulation can be calculated as:

$$\text{Years to Payback} = (Ci \times R1 \times R2 \times E) \div \{(Ceh \times [R2 - R1] \times HDD \times 24) + (Cec \times [R2-R1] \times CDD \times 24)\}$$

where:

Ci = square foot cost of EIFS
R1 = Initial R value
R2 = Final R value
E = System efficiency
Ceh = Cost of heating per Btu
HDD= Heating degree days
Cec = Cost of cooling per Btu
CDD= Cooling degree days

Assuming:

- a cost of EIFS of $11.95 per sq ft (drained EIFS cost per Dryvit + 20 percent)
- an initial R value of 2
- a final R value of 13
- a system efficiency of 0.88
- a cost of heating per BTU of $1.20 / 100,000
- an HDD for northern VA of 4100 (ASHRAE 90.1-2007)
- a cooling cost of $0.08/3,412, a CDD of 3,900.

Therefore:

(11.95 x 2 x 13 x 0.88) / {(0.000012 x [13-2] x 4100 x 24) + (0.00003 x (13-2) x 3900 x 24)} = 8.6 yrs.

Addition of insulation at a cost of up to $23.00/sq ft is of value and produces reasonable payback assuming a 12-yr payback.

Glass replacement

According to the calculations done by the National Renewable Energy Laboratory (NREL) of the DOE for energy savings using provided whole building energy analysis, calculations were done on a per square foot for Kingman and TEC buildings.

The cost to replace glass with insulating glass on the TEC building at $35/sq ft, and on the Kingman building at $45. The cost to change the U factor of 6.12 (for a single pane, non-thermally broken window and a Solar Heat Gain Coefficient (SHGC) of 0.58 for single pane tinted glass) to a thermally broken aluminum curtain wall with insulated tinted Low-E glass and a U factor of 0.44 and SHGC of 0.3, will result in an annual energy savings of $23,797 for the TEC building and $13,126 for Kingman. The first cost for this change will be $1,092,000 for the TEC building and $774,000 for Kingman building, resulting in simple paybacks (without interest and energy cost increase) of 45 and 56 yrs, respectively. Based on high payback values, glazing replacement in these buildings is not recommended. In these buildings infiltration is not a concern, since glazing systems are fixed on these buildings.

Other measures

Other measures recommended such as vestibules, gasketing, and air sealing are common sense, and experience shows that a return on investment of 3-5 yrs is to be expected. The Kingman hearing room insulation should be considered cost-effective at a payback of 22 yrs (new limit for ASHRAE 90.1 – 2010 is 40 yrs), because of ceiling replacement that boosts the cost.

Lighting

LI-1. Remove center lamp from the 3-lamp fixtures in private offices and work spaces around the perimeter in the Kingman Building (Bldg 2593)

Existing conditions

In most private offices and work spaces around the perimeter, the lighting fixtures are 2x4-ft, 3-lamp (T8) parabolic troffers. Lighting levels range from 70 to 130 foot-candles. Since the fixtures are low glare parabolic types, the higher levels could be reduced with insignificant impact on occupant comfort.

Solution

Remove the center lamp from the 3-lamp fixtures in the private offices and work spaces around the perimeter in Kingman. This could be done to approximately 1500 fixtures.

Savings

Savings accrue from reduced electrical energy use for an average of 12 hrs per day. Roughly calculated savings, assuming 35W per T-8 lamp and ballast, are:

(35W x 1500 fixtures x 12 x 260)/1000 = 163,800 kWH/yr x $.049/kWH
= $8,026/yr.

Investments

Using a $47/hr labor rate with 0.5 hr per fixture to remove the lamp and ballast, the estimated cost is $23.50 per fixture, or $35,250 total.

Payback

The resulting payback period is approximately 4.5 yrs.

LI-2. Complete the installation of occupancy sensors in restrooms in the Bldg 2592

Existing conditions

In many cases, the lighting in the restrooms in the Building is left on 24 hrs/day. Occupancy sensors have already been installed in the restrooms of the other buildings, but not yet in the restrooms.

Solution

Complete the (already programmed) installation of occupancy sensors in the restrooms in to turn off the lighting when the rooms are unoccupied, which could be as much as 50 percent of the time.

Savings

Savings accrue from reduced electrical energy use for an average of 12 hrs per day. Roughly calculated savings, assuming an average of 16 T-8 lamps (at 35 watts per T-8 lamp and ballast) for a typical restroom, are:

(35 watts x 16 lamps x 12 x 365)/1000 = 2,453 kWH/yr x $.049/kWH
= $120/yr per restroom.

Investments

Using $70 per occupancy sensor and a $47/hr labor rate with 0.5 hr per restroom to install the occupancy sensor, the estimated cost is $94 per restroom.

Payback

The resulting payback period is less than 1 yr.

LI-3. Replace the obsolete main switchboard in the Bldg 2592

Existing conditions

The existing main switchboard is early 1970s vintage with obsolete protective devices. Used replacement parts or devices are occasionally difficult to obtain and can cost 1.5 to 2 times the cost of equivalent new up-to-date equipment. Specially fabricated parts, when required, can be even more costly.

In addition, this represents a potential reliability issue that could lead to downtime for computers and facility occupants. If no spares are available, failure of a protective device could cause downtime as well as the need to prioritize other less critical loads.

Solution

Since space is apparently available in the equipment room, new equipment, tapped from the existing main bus, could be added without first having to remove the existing equipment. This new equipment would, at least initially, be used for spare and additional circuit needs, but could eventually replace the existing equipment totally.

This would reduce costs, reduce potential downtime for computers and facility occupants, and facilitate the addition of circuits and distribution equipment for equipment additions.

Savings

Savings accrue from the reduced cost of new parts and devices compared to used or specially fabricated replacement parts and devices. A typical size new feeder breaker could cost approximately $5,000, while the equivalent used or specially fabricated device could cost twice that much. The estimated savings could be as much as $5,000 per occurrence.

Investments

The installed and wired cost for a new expandable main switchboard section with main breaker and a bused section for the addition of feeder breakers as needed is estimated to be around $50,000.

Payback

Assuming the need for two new or replacement devices per year, the resulting payback period is approximately 5 yrs. This does not include the potential cost of downtime if a used replacement device could not be readily obtained.

LI-4. Replace the obsolete motor control centers in the Bldg 2592

Existing conditions

The existing motor control centers are early 1970s vintage with obsolete motor starters and protective devices. Used replacement parts, starters, or devices are occasionally difficult to obtain and can cost 1.5 to 2 times the cost of equivalent new up-to-date equipment. Specially fabricated parts, when required, can be even more costly.

In addition, this represents a potential reliability issue that could lead to downtime for computers and facility occupants. If no spares are available, failure of a starter or protective device could cause downtime as well as the need to prioritize other less critical motor loads.

Solution

Since space is apparently available in the equipment room, new equipment, tapped from the existing main buses, could be added without first having to remove the existing equipment. This new equipment would at least initially be used for spare and additional circuit needs, but could eventually replace the existing equipment totally.

This would reduce costs, reduce potential downtime for computers and facility occupants, and facilitate the addition of motor circuits for equipment additions.

Savings

Savings accrue from the reduced cost of new parts and devices compared to used or specially fabricated replacement parts and devices. A typical size new motor starter could cost approximately $2,500, while the equivalent used or specially fabricated device could cost twice that much. The estimated savings could be as much as $2,500 per occurrence.

Investments

The installed and wired cost for a new expandable motor control vertical section, bused for the addition of starters as needed, is estimated to be around $15,000.

Payback

Assuming the need for two new or replacement starters per year, the resulting payback period is approximately 3 yrs. This does not include the potential cost of downtime if a used replacement part or starter could not be readily obtained.

LI-5. Install skylights and turn off the lights during the day at the Fitness Center/Mailroom (B2584), Museum/Motor Pool (B2585), Warehouse (B2582)

Existing Conditions

The lighting in these metal building spaces is pendant mounted from the roof and is turned on at least 12 hrs per day. The building type lends itself to the installation of skylights.

Solution

In conjunction with a possible roof replacement, install skylights and turn the artificial lighting off completely. Re-install the existing lighting fixtures after roof replacement in case the buildings are used at night.

Savings

Savings accrue from reduced electrical energy use for an average of 12 hrs per day. Roughly calculated savings, assuming a total of 50 2-lamp (T-8) lighting fixtures (at 70W per fixture), are:

(70W x 50 fixtures x 12 x 260)/1000 = 10,920 kWH/yr x $.049/kWH = $535/yr.

Investments

The cost of re-installing the existing lighting fixtures would be an embedded necessary part of the roof replacement. The installed cost of a 4x4-ft skylight is estimated to be around $200. Since only about half as many skylights would be needed as compared to lighting fixtures, the total cost would be about $5,000.

Payback

The resulting payback period is just over 9 yrs.

LI-6. Upgrade the lighting fixtures in the Grounds Equipment Facility, Bldg 2583, to new lower wattage, more energy efficient types

Existing conditions

The existing lighting in the grounds maintenance facility consists of six, 2-lamp (T-12), non-energy efficient type, fluorescent pendant lighting fixtures and another five high wattage (assumed to be 200W each) incandescent pendant lighting fixtures. Today's state of the art lighting fixtures are much more energy efficient than the ones currently used in the grounds maintenance facility.

Solution

Upgrade the current lighting in the grounds maintenance facility to new energy efficient 2-lamp (T-8) lighting fixtures. This would require about 10 new lighting fixtures totaling 700W (at 70W per fixture) compared to the existing total of 1600W (6 x 100 for the fluorescent fixtures plus 5 x 200 for the incandescent fixtures).

Savings

Savings accrue from reduced electrical energy use for an average of 12 hrs per day. Roughly calculated savings are:

$$([1600-700] \times 12 \times 260)/1000 = 2{,}808 \text{ kWH/yr} \times \$.049/\text{kWH} = \$138/\text{yr}.$$

Investments

Using $47 per new lighting fixture and a $47/hr labor rate with 1.5 hr per fixture to remove the old and re-install the new, the estimated cost is $117.50 per fixture, or $1,175 total.

Payback

The resulting payback period is approximately 8.5 yrs.

LI-7. Upgrade the lamps and ballasts in the existing lighting fixtures in the bunker facilities, Bldgs 2590 and 2591, to new lower wattage, more energy efficient types

Existing conditions

The existing lighting in the bunker facilities consists of primarily of 2-lamp (T-12), non-energy efficient type, fluorescent lighting fixtures. There are approximately 200 light fixtures total in the two buildings. Today's state of the art lamps and ballasts are much more energy efficient than the ones used in the existing fixtures.

Solution

Upgrade the current lamps and ballasts in the bunker facilities to new energy efficient T-8 lamps and electronic ballasts. This would require about 400 new lamps and 200 new ballasts totaling 14,000W (at 70W per fixture) compared to the existing total of 20,000W (at 100Wper fixture).

Savings

Savings would accrue from reduced electrical energy use when the lights are turned on. The bunker facilities are not normally occupied. Provided the lights are not left turned on when the facilities are not occupied, upgrading the lamps and ballasts cannot be justified based on minimal savings from reduced electrical energy use.

Investments

Using $47 per ballast and pair of new lamps and a $47/hr labor rate with 1 hr per fixture to remove the old and re-install the new, the estimated cost is $94 per fixture, or approximately $18,800.

Payback

The resulting payback period for these facilities would be well over 20 yrs.

HVAC-1. Upgrade HVAC system in Kingman Building, Bldg 2593

Existing conditions

The Kingman building is a 94,000 sq ft office building built in 1973. It has three floors above the ground floor. The building's exterior is not energy efficient (walls consist mostly of single pane glass). The HVAC system is an induction type air terminal system (Figure 18) in the perimeter offices with the interior spaces served by a constant temperature constant volume air-conditioning system. In the perimeter corridors there is a radiant fin tube heating system. The third floor was converted to a variable air volume (VAV) system several years ago. This ECM applies only to the first and second floors of the building.

There are two air handling units (AHUs) that provide air to these spaces. One sends air to the induction units. There are four zones off this unit each with a booster fan to provide the needed pressure to achieve the induction of room air through the air terminal units. The induced room air passes through a heating/cooling coil located in the air terminal unit to provide individual room temperature control for those spaces along the perimeter of the building. The heating and cooling coils are supplied with tempered water that comes from one of four pumped water systems.

Figure 18. Induction unit with cover off.

Each system or zone supplies water to units having a similar exposure. Thus there are zones covering different sides of the building. The spaces that are not on the exterior of the building are provided air from the other AHU, which is a constant flow and constant temperature system. All of the interior spaces get the same temperature air. The HVAC equipment operates continuously even thought the occupancy is approximately 12 hrs per day, Monday through Friday.

The first and second floors of the building have a number of problems. The building envelope performs poorly with infiltration of outside air noticeable, significant heat loss/gain through the windows and huge swings in solar heating loads due to the suns position relative to the building. The solar loads pose the greatest issue with discomfort of the building's occupants. Since the HVAC system does not respond well to changing loads, the offices on the east side are too hot in the morning and those on the west side are hot in the afternoon. These conditions influence adjacent spaces and interior offices are also uncomfortable. The degree of occupant discomfort is evident by the number of circulating fans and small space heaters located in most spaces. In one section of the first floor, a supplemental air-conditioning unit has been installed on the roof to provide additional cooling. Maintenance costs are rising since the HVAC system is old and it is getting quite difficult to obtain repair parts for the induction units and other components.

Finally, with all the distractions caused by the uncomfortable temperatures, the productivity of the government employees suffers significantly. In the Inspector General's office area on the first floor, space temperatures were measured to be in the range of 67 to 69 °F when it was approximately 45 °F outside. Other building spaces had temperatures in the range of 70 to 78 °F in the morning of a cloudy day. Measurements near the windows found temperatures of 66 °F a few inches from the window, which increased to 71 °F when the distance was increased to 3 ft. The result of these low temperatures near the windows is desks in most offices are placed some distance from the perimeter wall thus reducing the usable floor space of the building.

The air flow in the building was also causing problems. It was found that, on the first floor near the Board Room and Hearing Room, the downstairs return-air fan was causing a significant negative pressure. The cause is unknown (a closed damper, some blockage in the duct system, etc.). Because of this negative pressure an excessive amount of outdoor air was infiltrating into the building. This was resulting in high moisture levels in the Board Room requiring the operation of a space dehumidifier. Also, cold air was noted to be entering the Inspector General's office area through a return air grill, which was contributing to the coldness of that space.

Solution

The existing air-conditioning system needs to be replaced or upgraded to accomplish individual room temperature control. The induction units need to be replaced with either new induction units having a remote thermostat, a variable air volume system, or a four-pipe fan coil system. A ceiling mounted radiant heating/cooling system combined with a dedicated outdoor supply air unit was also considered for this building, but its initial cost would exceed the other options.

Along with any air-conditioning improvements the thermal properties of the building envelope need improving. The solar load needs to be greatly reduced by shading. And the infiltration of outdoor air needs to be controlled by sealing those openings in the outer walls.

There should be carbon dioxide sensors located in the return air ducts that would monitor the occupancy levels and adjust the outdoor air quantity accordingly.

Energy savings

HVAC 1a - VAV system option

A VAV system would provide savings through reduced air flow to spaces not requiring maximum cooling. The reduced air flow would occur most of the time. Due to the solar load on the building the zones, the eastern exposure will have high air flow rates in the morning and in the afternoon the air flow rates will drop since the sun has moved to the west side of the building.

The western side will experience a similar change in load. The average performance of the VAV system will result in a reduced air flow to approximately 80 percent of the original flow during the occupied hours in the day. The normal building occupancy is 60 hrs per week leaving the building unoccupied 108 hrs per week. During these off hours, the building may have an occasional occupant so the HVAC system will not be turned off, but the air flow could be reduced to 30 percent of the original flow. This air flow reduction will provide a fan horsepower savings of more than 50 percent during occupied hours and 80 percent during unoccupied hours. For AHU #5 and #6, the total brake horsepower of the supply fans and return air fans is 81 hp and 18 hp, respectively.

With these fans operating 24 hrs per day, the fan electrical use reduction is 37 kW during operating hours and 59 kW at night for an estimated savings of 448 thousand kWh/yr. The cooling energy saving during the reduced air flow will result from the reduced outside air load and the reduced fan horsepower heat experienced by the cooling coil. This is estimated to be 20 percent of the cooling energy use, which amounts to 59,000 kWh/yr:

Fan Motor Electrical Savings = 99 hp x 0.746 kW/hp x 3120 hr/yr x 50%
+ 99 hp x 0.746 kW/hp x 5640 hr/yr x 80% = 448,000 kWh/yr
Outside air cooling saving = 236 tons x 250 full load hrs x 1 kW/ton-hr
= 59,000 kWh/yr

Providing comfortable conditions in the offices will eliminate the need for personnel heaters and cooling fans. If this equipment is not operated, an estimated energy saving of 36,000 kWh for no personnel heaters and 2,000 kWh for no fans would result. The total estimated annual savings is 38,000 kWh/yr for a cost savings of almost $1,900:

Electrical savings	= (100 fans x 39W + 100 heaters x 900W) 20 hrs/wk x 20wk/yr = 38,000 kWh/yr
Total electrical savings	= 545,000 kWh/yr
Electrical Cost Savings	= 545,000 kWh/yr x $0.049/kWh = $26,700/yr

This system will also handle a reduced amount of air that results in bringing less outside air, which will yield a heating energy savings of 892 million Btu/yr:

Heating energy saving	= 61,300 CFM x 20% x 1.08 x (68°F – 42°F) x 108 hrs/wk x 24 wks/yr/ 70% boiler efficiency = 1,270 million Btu/yr
Heating cost savings	= 1,270 million Btu/yr x $12/million Btu = $15,200/yr

The use of a VAV system will reduce the maintenance costs by an estimated 50 percent since the original system uses old equipment, which has parts that are difficult to find. A VAV will also include better controls, which will result in more comfortable conditions thus reducing the number of maintenance calls. The normal maintenance cost for the induction system is estimated to be 5 percent of the installed cost of $750,000, or $37,500/yr. A 50 percent increase to this amount is $18,750.

The total estimated cost savings provided by the VAV system equals $60,650/yr

HVAC 1b - New induction units option

Providing new induction units will give the system new room controls so the air-conditioning system can better regulate space temperatures. New units will have induction nozzles that will perform better than those in the old units so more air flow will pass through the units. The dampers in the unit will also perform better, thereby improving the temperature control in spaces. During the unoccupied hours, the induction system can provide temperature control with a minimum air flow. In the winter, space heat can be provided by circulating warm water through the coils in the induction units (air flow is not required). During the cooling season, space temperatures can be maintained with a minimum air flow. A fan energy savings of 227,000 kWh/yr would result from limited fan operation during the unoccupied hours.

It is estimated that the booster fans (36HP) would be shut down during unoccupied times and the supply and return fans (27 hp + 9 hp) would operate at a rate of 50 percent during this time period:

Fan Motor Electrical Savings = 36 hp x 0.746 kW/hp x 5640 hr/yr x 100% + 36 hp x 0.746 kW/hp x 5640 hr/yr x 50% = 227,000 kWh/yr

The internal spaces, which are now conditioned with a constant volume system, would be changed to a VAV system much like the description above. This will yield an energy savings during both occupied and unoccupied times of 122,000 kWh/yr:

Fan Motor Electrical Savings = 27 hp x 0.746 kW/hp x 5640 hr/yr x 80% + 27 hp x 0.746 kW/hp x 3120 hr/yr x 50% = 122,000 kWh/yr

The cooling energy saving during the reduced air flow will result from the reduced outside air load and the reduced fan horsepower heat experienced by the cooling coil. This is estimated to be 20 percent of the cooling energy use, which amounts to 59,000 kWh/yr:

Outside air cooling saving = 236 tons x 250 full load hrs x 1 kW/ton-hr
= 59,000 kWh/yr

The savings of avoided use of personal heating equipment and fans is the same as with the VAV system option, which is 38,000 kWh/yr. The VAV system option maintenance savings also applies to this system option. The estimated heating energy savings are also the same as the VAV system option:

Total electrical savings	= 227,000 kWh/yr + 122,000 kWh/yr + 59,000 kWh/yr + 38,000 kWh/yr = 446,000 kWh/yr
Electrical Cost Savings	= 446,000 kWh/yr x $0.049/kWh = $21,800/yr
Heating energy saving	= 61,300 CFM x 20% x 1.08 x (68°F – 42°F) x 108 hrs/wk x 24 wks/yr / 70% boiler efficiency = 1,270 million Btu/yr
Heating cost savings	= 1,270 million Btu/yr x $12/million Btu = $15,200/yr

Maintenance savings are $18,750.

The total estimated cost savings provided by the Induction system option equals $55,750/yr.

HVAC-1c. Fan coil option

The estimated fan coil saving would be similar to that provided by the new induction system, or approximately $55,750/yr.

Investment

The VAV system option would require two new AHUs, new air distribution system for the perimeter rooms, new VAV boxes, and new air distribution system to the first and second floor interior offices, and a new perimeter radiant heating system. The existing control system would be upgraded to monitor space temperatures in all zones of the building. The installation of this system would require a new ceiling since the old ceiling would have to be removed to install the new air distribution system. The total estimated cost for these modifications would be $628,500. This would not include the cost of relocating the building occupants during the time required to install the VAV system.

The new induction system option would include new induction units in each perimeter room, a new VAV system for the interior spaces, and new controls for a total estimated cost of 484,000.

A four pipe fan coil system with a new dedicated outdoor air system (DOAS) would require a new pipe distribution system, new fan coils, new DOAS supply air unit, and new air distribution system plus controls. The estimated cost would approach $700,000. Since this is the most expensive and would not offer additional savings, it will not be furthered considered.

Payback

The resulting payback period of the VAV system option is 10.4 yrs:

$628,000/ $60,650/yr = 10.4 yrs

The resulting payback period of the induction air-conditioning system option is 8.7 yrs:

$484,000/ $55,750/yr = 8.7 yrs

HVAC-2. Replace HVAC system with VAV in Cude Building, Bldg 2592

Existing Conditions

Bldg 2592 was constructed in 1971 as a laboratory and thus has a 12-ft high ceiling to house the required equipment. It is now used mainly as an office building. Like the Kingman Building, the building has large areas of single pane glass for the outer walls and there is no external shading to stop sunshine from entering office spaces. There are numerous complaints regarding the glare and warm room temperatures caused by this sunshine through the high windows.

The building has an attached “Annex,” a restricted area that houses data processing equipment. This area was not surveyed and it not part of this ECM.

The HVAC equipment consists of four large air handlers located in their own penthouse structures on the roof. There are two chillers and boilers in the basement mechanical room. It is understood that the HVAC system has VAV boxes serving zones in the building, but there are no controls to adjust the AHU air flow. Heating is provided by a perimeter radiant heating system. The general building space temperature was a comfortable 74 °F, and the supply temperatures varied from 58 to 61 °F. This equipment operates continuously for proper temperature control. The building is typically occupied 6:30 a.m. to 6:30 p.m., Monday through Friday.

Solution

The existing air-conditioning system needs to be replaced with a VAV type to maximize energy savings. This will require new VAV boxes for each zone and new AHUs for each of the four penthouses. The new AHUs will have variable speed drives on the fan motors, which will reduce electrical use when not at maximum air flow.

Occupancy sensors will be placed in the office spaces and will monitor concentrations of carbon dioxide. The level of CO_2 in the return air is directly related to the level of building occupancy. When the CO_2 levels are low, the outside air dampers can be closed to save the energy required to temper this outside air.

Savings

Installing a VAV system will yield a number of energy savings. First there would be fan energy savings. By varying the air flow only enough air is delivered to spaces that will deliver the required cooling. The fans would typically operate during the occupied hours, on average at 80 percent of full flow. Since power savings is proportional to the cube of the air flow reduction this amount to a 50 percent energy savings. During unoccupied hours, the flow can be reduced even further and the estimated fan motor energy saving would be an average of 80 percent:

Fan Motor Electrical Savings = 198 hp x 0.746 kW/hp x 5640 hr/yr x 80% + 198 hp x 0.746 kW/hp x 3120 hr/yr x 50% = 897,000 kWh/yr

There is an estimated 1250 equivalent cooling full load hours during the cooling season for this site. The cooling energy saving during the reduced air flow will result from the reduced outside air load and the reduced fan horsepower heat experienced by the cooling coil. This is estimated to be 20 percent of the cooling energy use, which amounts to 64,000 kWh/yr:

Outside air cooling saving = 258 tons x 250 full load hrs x 1 kW/ton-hr
= 64,000 kWh/yr
Total electrical savings = 897,000 kWh/yr + 64,000 kWh/yr = 961,000 kWh/yr
Electrical Cost Savings = 961,000 kWh/yr x $0.049/kWh = $47,100/yr
Heating energy saving = 113,000 CFM x 10% x 1.08 x (68°F – 42°F) x 108 hrs/wk
x 24 wks/yr /70% boiler efficiency = 1,175 million Btu/yr
Heating cost savings = 1,175 million Btu/yr x $12/million Btu = $14,100/yr

The total estimated cost savings provided by the new VAV system equals $61,200/yr.

Investments

The cost of replacing the four AHUs will be approximately $60,000 each for a total of $240,000. Providing VAV boxes and downstream air distribution components in the office space plus a control system has an estimated cost of $394,000. The total cost for a VAV system is therefore $634,000.

Payback

The resulting simple payback is 10.4 yrs:

$634,000 / $61.200/yr = 10.4 yrs

HVAC-3. Improve HVAC system controls in Cude Building, Bldg 2592

Existing conditions

As discussed in ECMs HVAC-1 (p 30) and HVAC-2 (p 31), the HVAC system in this building operates continuously. The building is typically occupied 6:30 a.m. to 6:30 p.m., Monday through Friday. There is no adjustment of air flow rates and space temperatures during the unoccupied periods.

Solution

Controls can be added to this building that would allow the space temperature to be setback to a less energy intensive level during unoccupied periods. The occupancy level can be monitored to close off the outdoor air intake when there is no one in the building. Variable frequency drives can be added to the fan motors so the air flow can be reduced during unoccupied hours.

Energy savings

The existing air-conditioning system's air flow can be reduced during the unoccupied time periods and still maintain the relaxed space temperatures of 78 °F during the cooling season and 62 °F in the heating season. There will be a fan motor energy saving, a cooling saving and a heating energy saving. The estimated air flow would average 70 percent of the current air flow, which would result in a 60 percent fan horsepower savings. The cooling energy reduction is estimated to be approximately 10 percent, or 125 equivalent full load hours. The heating savings is estimated to 15 percent of the current annual use of 72,079 therms:

Fan Motor Electrical Savings = 198 hp x 0.746 kW/hp x 5640 hr/yr x 60%
= 500,000 kWh/yr

Temperature setback savings:

Cooling saving = 258 tons x 125 full load hrs x 1 kW/ton-hr = 32,000 kWh/yr
Heating savings = 72079 therms x 15% = 10,800 therms, or 1,080 million Btu/yr

The cooling energy saving during the reduced air flow will result from the reduced outside air load and the reduced fan horsepower heat experienced by the cooling coil. This is estimated to be 20 percent of the cooling energy use, which amounts to 64,000 kWh/yr:

Outside air cooling saving	= 258 tons x 250 full load hrs x 1 kW/ton-hr
	= 64,000 kWh/yr
Heating energy saving	= 113,000 CFM x 10% x 1.08 x (68°F – 42°F)
	x 108 hrs/wk x 24 wks/yr /70% boiler efficiency
	= 1,175 million Btu/yr
Total electrical savings	= 596,000 kWh/yr
Total electrical Cost Savings	= 596,000 kWh/yr x \$0.049/kWh = \$29,200/yr

Total heating savings	= 1,175 million Btu/yr + 1,080 million Btu/yr
	= 2,255 million Btu/yr
Total heating cost savings	= 2,255 million Btu/yr x $12/million Btu
	= $27,000/yr
Total cost savings	= $56,200/yr

Investments

The estimated cost to install controls to setback space temperatures and measure carbon dioxide for varying outside air is $40,000. The cost to add variable frequency drives to the supply and return air fans is estimated to be $68,000 for a total project cost of $104,000.

Payback

The resulting simple payback is 1.8 yrs:

$104,000/$56,200/yr = 1.8 yrs

HVAC-4. Temperature setback in Fitness Center/Mailroom, Bldg B2584, Museum/Motor Pool, Bldg B2585, Warehouse, Bldg B2582

Existing conditions

In several small buildings (cf. Figure 19), heating is accomplished by hot water unit heaters and radiators. These heaters are set to maintain a temperature during both occupied and unoccupied hours. There are no controls to adjust temperatures when the building is vacated.

Solution

Controls can be added to the heating systems of these building that would allow the space temperature to be set back to a less energy intensive level during unoccupied periods. This type of control is called “night setback.” The controls will also monitor the outdoor temperature and schedule the heating systems to warm-up the buildings so temperatures will be comfortable when occupancy begins.

Figure 19. Fitness Center/Mailroom and Museum/Motor Pool Buildings

Energy savings

The estimated energy savings provided by night setback controls is 15 percent of the winter heating energy use. These three buildings consumed 16,136 therms of natural gas during the winter heating season of 2005/2006:

Heating energy savings	= 1,614 million Btu/yr x 15% = 242 million Btu/yr
Heating cost savings	= 242 million Btu/yr x $12/million Btu = $2,900/yr

Investment

The estimated cost to install controls to setback space temperatures in these three buildings is $8,000.

Payback

The resulting simple payback is 2.8 yrs:

$8,000/$2,900/yr = 2.8 yrs

EL-1. Use energy efficient electric motors — installation-wide

Existing conditions

Electric motors are required to power a wide range of equipment and devices (e.g., Figure 20). The loads on the motors can vary or be relative constant. When selecting a motor, it is best to match the process load to the proper motor size. A partially loaded motor operates at a lower efficiency than one fully loaded. Sine motors that are not a premium type were found at Bldgs 2592 and 2593; the situation probably exists site-wide.

Motor efficiency ranges from 75 percent for a standard one horsepower (hp) three-phase induction motor operating at full load to 90 percent for a standard 50 hp motor. In 1992, the Energy Policy Act was passed that required most motors manufactured after October 1997 to meet higher efficiency standards. The efficiency set for 1 and 50 horsepower motors was 82.5 and 93 percent respectively. Later premium efficient motors became available at extra cost whose efficiencies range from 85.5 to 94.13 percent for the same range of motors. Single phase motors are normally 5 to 10 percent lower in efficiency. Another benefit of the higher efficient motors is that they run cooler and should provide a longer life of service.

Electric motors have a limited life. When they become inoperable, they typically can be repaired by rewinding to become functional again. A downside to this repair is a loss in efficiency. It is often more economical to replace a burnt out motor with a new premium motor than to rewind it. The cost difference between operating the two motors will easily pay for the extra cost of the new one.

Figure 20. Pump motor

Solution

At a number of electric motors that were not the premium efficiency type were found. The following standard and high efficient horsepower motors were found in Bldg 2592 that powered pumps:

- 10 hp pump motor @ 86% efficiency
- 20 hp pump motor @ 89.5% efficiency
- 25 hp pump motor @ 89% efficiency.

It is recommended to replace these motors and others that fail at with premium efficient motors when they fail and need replacement. The following Tables show the annual savings and the cost of the premium motors compared to the use of standard efficiency motors. The analysis shown in the Tables assume that the motors operate continuously and are fully loaded. The cost used in the simple payback calculation is half the premium cost, which approximates the cost of a new motor compared to rewinding a failed motor. If such a motor replacement program is not provided, energy will be wasted since the most efficient equipment is not used.

Savings

Tables 3 and 4 list the estimated saving of operating a premium efficient motor instead a less efficient motor, based on continuous operation. The estimated savings of the identified pump motors is 8,300 kWh/yr for a $407 annual cost savings, assuming that these motors are operating half the time.

Investments

Tables 3 and 4 also list the cost of new premium efficient motors. If the simple payback calculations assume that: the cost of rewinding the old motor is half the cost of a new premium efficient motor; and the estimated cost to replace these motors is $2,496; then the additional cost compared to rewinding the motors would be $1,248.

Payback

Tables 3 and 4 list the simple payback of installing a new premium efficient motors. The resulting payback period for the subject motors at the time of rewinding is 3.1 yrs.

Table 5. Premium efficiency OF standard motors.

Motor Size	Existing Efficiency (%)	Proposed Efficiency (%)	Energy Saved (kWh/yr)	Energy Cost Savings ($/yr)	Total Cost Premium ($)	Additional Cost of New Motor vs. Rewinding	Simple Payback (yrs)
25	89.00%	93.60%	7,515	$368	$975	$488	1.3
20	88.00%	93.60%	7319	$359	$850	$425	1.2
15	87.50%	93.00%	5391	$264	$671	$335	1.3
10	86.00%	91.70%	3,725	$183	$520	$260	1.4
7.5	85.50%	91.00%	2,696	$132	$424	$212	1.6
5	85.00%	89.50%	1,470	$72	$295	$144	2.0
3	82.00%	89.70%	1,470	$72	$230	$115	1.6
1	76.00%	85.50%	621	$30	$185	$93	3.1

Table 6. Premium efficiency OF post-1997 motors.

Motor Size	Existing Efficiency (%)	Proposed Efficiency (%)	Energy Saved (kWh/yr)	Energy Cost Savings ($/yr)	Total Cost Premium ($)	Additional Cost of New Motor vs. Rewinding	Simple Payback (yrs)
25	91.70%	93.60%	3,104	$152	$975	$488	3.2
20	91.00%	93.60%	3,398	$167	$850	$425	2.6
15	91.00%	93.00%	1,960	$96	$671	$335	3.5
10	89.50%	91.70%	1,438	$70	$520	$260	3.7
7.5	88.50%	91.00%	1,225	$60	$424	$212	3.5
5	87.50%	89.50%	653	$32	$295	$144	4.5
3	86.50%	89.70%	588	$29	$230	$115	4.0
1	82.50%	85.50%	196	$10	$185	$93	9.7

4 Conclusions and Recommendations

In this work, a professional Energy Team composed of researchers from the Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) and other subject matter experts conducted an Energy Optimization Assessment at the Humphreys Engineer Center, Alexandria, VA, to identify energy inefficiencies and wastes, and to propose energy-related projects that could enable the installation to better meet the energy reduction requirements mandated by Executive Order 13123, the Energy Policy Act (EPACT) of 2005, and the Energy Independence and Security Act (EISA) of 2007.

The Assessment included a Level I study and analysis of building envelopes, ventilation air systems, and lighting, of the following administrative buildings:

- Kingman (B2593)
- Casey (B2594)
- Cude (B2592)
- Fitness Center/Mailroom (B2584)
- Museum/Motor Pool (B2585)
- Warehouse (B2582)
- Grounds Equipment (B2583)
- Bunkers (B2590, 91 and B2595) Buildings.

The study identified 31 different energy conservation measures (ECMs). Appendix A to this report (Table A1) lists economically evaluated ECMs, including measures related to the building envelope, lighting, HVAC and electrical systems, which, if implemented, would reduce Humphreys Engineer Center annual energy use by up to 14,500 MMBtu/yr and 2,300 MWh/yr (depending on the combination of ECMs implemented). Eighteen of the proposed energy conservation measures were quantified economically and offer potential annual savings of more than $200,000.

This work recommends that the Humphreys Engineer Center implement the identified low-cost, short-term payback ECMs (lighting and electrical) as a part of its annual O&M program. This work also identified major energy savings that will result from building insulation and that will require significant investments. It is also recommended that HEC consider implementing these projects using an Energy Performance Contracting mechanism, or through Federal technology demonstration programs. These projects can be packaged with the HVAC system improvement projects, which in combination will result in a reduction of first costs, thereby becoming more attractive to ESPC contractors.

Acronyms and Abbreviations

Term	Spellout
AHU	air handling unit
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BTU	British Thermal Unit
CDD	cooling degree days
CEERD	U.S. Army Corps of Engineers, Engineer Research and Development Center
CERL	Construction Engineering Research Laboratory
CFM	cubic feet per minute
DOAS	dedicated outdoor air supply
DOE	U.S. Department of Energy
ECBCS	Energy Conservation in Buildings and Community Systems
ECM	Environmental Climate Model
EIFS	Exterior Insulation Finishing System
EISA	Energy Independence and Security Act
EPAct	Energy Policy Act
EPDM	EPDM (ethylene propylene diene M-class [rubber])
ERDC	Engineer Research and Development Center
ESPC	Energy Savings Performance Contract
FEMP	Federal Energy Management Program
HDD	heating degree days
HEC	Humphreys Engineer Center
HECSA	Humphreys Engineer Center Support Activity
hp	horsepower
HVAC	heating, ventilating, and air-conditioning
IEA	International Energy Agency
NREL	National Renewable Energy Laboratory
O&M	operations and maintenance
SCIF	sensitive compartmented information facility
SHGC	Solar Heat Gain Coefficient
SPF	spray polyurethane foam
TEC	Topographic Engineering Center
TR	Technical Report
USACE	U.S. Army Corps of Engineers
VAV	variable air volume
WWW	World Wide Web

Appendix A: Summary of ECMs

Table A7. Summary of ECMs.

ECM #	ECM Description	Electrical Savings		Thermal		Maintenance $/yr	Total Savings $/yr	Investment $	Simple Payback yrs
		KWh/yr	$/yr	MMBtu/yr	$/yr				
BE-1A	Insulate the Kingman Building (Bldg 2593) on the exterior with a layer of 3-in. rigid insulation and a drainable External Insulation Façade System (EIFS).			1,805	21,670		21,670	260,000	12
BE-1B	Add curtain wall with insulated Low-E gazing and with insulated metal backpan spandrel areas of the Kingman Building (Bldg 2593).			1,094	13,126		13,126	774,000	59
BE-1D	Take the ceiling down n the Kingman Building (Bldg 2593) hearing room, and insulate and seal the roof from inside with 3-in. of spray polyurethane foam			2,500	25,000		25,000	550,000	22
BE-2A	Insulate the Casey Building (Bldg 2594) on the exterior with a layer of 3-in. rigid insulation and drainable EIFS			1736	20,830		20,830	250,000	12
BE-3A	Install 3-in. of drainable EIFS on the face of the precast concrete of the Cude Building (Bldg 2592).			2,848	34,170		34,170	410,000	12
BE-3B	Removed the single glazing adaptor, and replace existing single pain window glass with insulating Low E. in the Cude Building (Bldg 2592).			1,983	23,797		23,797	1,092,000	46
BE-3E	Add a vestibule to the courtyard door in the Cude Building (Bldg 2592). Doors should be regasketed.			420	5,000		5,000	20,000	4
BE-5B	Insulate Bunker Building (Bldg 2591) with drainable EIFS. Replace existing failed EIFS with new drainable EIFS			567	6,800		6,800	82,000	12
BE-5D	Gasket doors in Bunker Bldgs 2590, 2591, 2595.								< 1
LI-1	Remove center lamp from the 3-lamp fixtures in private offices and work spaces around the perimeter in the Kingman Building (Bldg 2593).	163,800	8,026				8,026	35,250	4.5
LI-2	Complete the installation of occupancy sensors in restrooms in the Cude Building (Bldg 2592).	2,453 per restroom	120 per restroom						< 1
LI-3	Replace the obsolete main switchboard in the Cude Building (Bldg 2592).		5,000 per occurrence				10,000	50,000	5
LI-4	Replace the obsolete motor control centers in the Cude Building (Bldg 2592).		2,500 per occurrence				5,000	15,000	3
LI-5	LI-5 Install skylights and turn off the lights during the day at the Fitness Center/Mailroom (B2584), Museum/Motor Pool (B2585), Warehouse (B2582).	10,920	535				535	5000	9
LI-6	Upgrade the lighting fixtures in the Grounds Equipment Building (B2583), to new lower wattage, more energy efficient types.	2,808	138				138	1175	8.5
LI-7	Upgrade the lamps and ballasts in the existing lighting fixtures in the bunker facilities, Bldgs 2590 and 2591, to new lower wattage, more energy efficient types.							18,800 94/per fixture	20

ECM #	ECM Description	Electrical Savings		Thermal		Maintenance	Total Savings	Investment	Simple Payback
		KWh/yr	$/yr	MMBtu/yr	$/yr	$/yr	$/yr	$	yrs
HVAC-1	Upgrade HVAC System in Kingman Building (Bldg 2593):								
	1a	545,000	26,700	1,270	15,200	-18,750	60,650	628,000	10.4
	1b	446,000	21,800	1,270	15,200	18,750	55,750	484,000	8.7
HVAC-2	Replace HVAC System with VAV in Cude Building (Bldg 2592).	961,000	47,100	1,175	14,100		61,200	634,000	10.4
HVAC-3	Improve HVAC System Controls in Cude Building (Bldg 2592).	596,000	29,200	2,255	27,000		56,200	104,000	1.8
HVAC-4	HVAC-5. Temperature Setback in Fitness Center/Mailroom (B2584), Museum/Motor Pool (B2585), Warehouse (B2582).			242	2,900		2,900	8,000	2.8
EL-1	Use Energy Efficient Electric Motors installation-wide.								3.1

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14. ABSTRACT

This work conducted an Energy Optimization Assessment at the Humphreys Engineer Center, Alexandria, VA, to identify energy inefficiencies and wastes, and to propose energy-related projects that could enable the installation to better meet the energy reduction requirements mandated by Executive Order 13123, the Energy Policy Act (EPACT) of 2005, and the Energy Independence and Security Act (EISA) of 2007. The study was conducted by a professional Energy Team, composed of researchers from the Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) and other subject matter experts. The Assessment included a Level I study of the installation administrative buildings, and an analysis of their building envelopes, ventilation air systems, and lighting. The study identified 31 different energy conservation measures (ECMs), including measures related to the building envelope, lighting, HVAC and electrical systems that, if implemented, would reduce Humphreys Engineer Center annual energy use by up to 14,500 MMBtu/yr and 2,300 MWh/yr (depending on the combination of ECMs implemented). Eighteen of the proposed energy conservation measures were quantified economically and have a potential of annual saving of more than $200,000.

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